

Swan Ponds stormwater facility: Temperature impacts to Tenny Creek

July 3 to October 18, 2003

Clark County Public Works Water Resources

Background

The Swan Ponds are an in-line stormwater facility located on Tenny Creek just downstream of NE 99th Street. Clark County Public Works built the ponds in 1993-1994 as stormwater mitigation for a 99th Street widening project (CRP #310722). The ponds were designed primarily as a detention facility in accordance with 1992 stormwater regulations.

The facility outlet is an overflow structure that skims off the uppermost layer of pond water and discharges it downstream. In 2002, County stormwater engineers in the Water Resources section requested that Water Resources monitoring staff conduct a temperature study to determine whether the outlet design was causing downstream thermal impacts by discharging heated surface water.

Purpose

To determine the extent of impacts from Clark County's Swan Ponds stormwater facility on downstream water temperature in Tenny Creek.

Decision Statement

In the event that the Swan Ponds facility causes downstream exceedance of state water temperature criteria, Clark County will evaluate opportunities to mitigate these impacts.

Design

Temperature loggers were deployed at the inlet (TEN055) and outlet (TEN050) to the Swan Ponds facility. An additional logger was placed in Tenny Creek just upstream of its confluence with Salmon Creek (TEN010), approximately one mile downstream from the Swan Ponds. Loggers were deployed on July 3, 2003 and retrieved on October 18, 2003 to capture potential impacts during the warmest part of the year.



Swan Pond outlet structure, looking upstream. Photo May 2004.

Methods/Quality Control

Hobo[®] Water Temp Pro data loggers were installed at station TEN055 and TEN050, and a Hobo[®] H8 data logger was installed at station TEN010. All loggers passed pre-deployment and post-deployment accuracy checks against a National Institute of Standards and Technology (NIST) certified thermometer. Additionally, each logger passed two field audits performed during the deployment period to verify field accuracy.

Loggers were tested and installed according to procedures outlined in Standard Procedures for Monitoring Activities: County Public Works Water Resources (2003). At station TEN055 and TEN010, loggers were attached to rebar driven into the creek bottom such that the loggers were suspended a few inches above the substrate. At station TEN050, the logger was suspended by a cable inside the outlet structure in an area of well-mixed flow.

Temperature readings were logged at 1-hour intervals. Hourly temperature data were analyzed in Excel using data-conversion macros and the Tempture (version 1.1) macro developed by the Oregon Department of Environmental Quality.

Statistical comparisons between the three loggers were performed using the large sample approximation of the sign test (Helsel and Hirsch, 1993). The sign test and Wilcoxon signed-rank test are non-parametric equivalents to the parametric paired t-test. All three are used to analyze differences between matched pairs of data, but the appropriate test must be chosen based on the characteristics of the dataset.

If the differences between data pairs follow a normal distribution (bell curve), the paired t-test is used. In the event that the differences follow a distribution that is symmetrical but not normal, the Wilcoxon signed-rank test is selected. If the differences are neither normally nor symmetrically distributed, the sign test is the appropriate choice. The sign test is simpler than the other two alternatives and tests a general hypothesis: does x tend to be higher (or lower, or different) than y. Based on a visual evaluation of histogram and probability-plot results, the differences between project data pairs do not follow a normal or symmetrical distribution. Therefore, the sign test was selected for this analysis.

For paired observations (x_i, y_i), the difference between each pair is computed. The sign test determines whether x_i and y_i are from the same population (the null hypothesis) by analyzing the sign of the differences. The null hypothesis that the difference between x and y is zero is rejected if sufficient differences exist, with the magnitude of the difference measured as the median difference between the matched pairs. The confidence interval on this difference is simply calculated as the confidence level on the median (Helsel and Hirsch, 1993).

Results

The State of Washington water quality criterion states that water temperature is not to exceed 63.5 °F (17.5 °C) in Tenny Creek (WAC 173-201A), measured as the 7-day average of the daily maximum temperature (7-DADMax). Table 1 below shows results from the three temperature stations from July 3 to October 18, 2003.

Site Name	Days > 64 F	7-Day averages				Seasonal Maximum		Seasonal Max ΔT	
		Date	Maximum	Minimum	ΔT	Date	Value	Date	Value
TEN010	0	07/21/03	59.7	57.5	2.2	09/11/03	60.8	10/06/03	4.2
TEN050	0	07/20/03	62.2	56.1	6.1	07/10/03	63.1	07/03/03	7.9
TEN055	0	07/20/03	56.9	54.5	2.4	10/06/03	58.8	10/06/03	5.3

Table 1. Summary of temperature logger results above and below the Swan Ponds, July 3-October 18, 2003.

All three stations met the 63.5 degree F criteria throughout the monitoring period. Moving from upstream to downstream, the maximums of the 7-day average for the Swan Ponds inlet, Swan Ponds outlet, and mouth of Tenny Creek were 56.9 degrees, 62.2 degrees, and 59.7 degrees, respectively.

Maximum *daily* values for the Swan Ponds inlet, Swan Ponds outlet, and mouth of Tenny Creek were 58.8 degrees, 63.1 degrees, and 60.8 degrees, respectively. The maximum daily changes in temperature (ΔT) for the Swan Ponds inlet, Swan Ponds outlet, and mouth of Tenny Creek were 5.3 degrees, 7.9 degrees, and 4.2 degrees, respectively.

Results of one-sided sign test comparisons between TEN050 vs TEN055 and TEN010 vs TEN055 are shown in Table 2. The tests were run using n=108 pairs of daily maximum

temperature values, with $\alpha = 0.05$. Also included in Table 2 are the results of a two-sided sign test for TEN010 vs TEN050.

	TEN050 vs TEN055 (SP outlet vs SP inlet)	TEN010 vs TEN055 (crk mouth vs SP inlet)	TEN010 vs TEN050 (crk mouth vs SP outlet)
Null hypothesis (H_0)	Prob [$x > y$] = 0.5	Prob [$x > y$] = 0.5	Prob [$x > y$] = 0.5
S statistic	100	99	99
Decision rule	reject H_0 if $Z \geq 1.645$	reject H_0 if $Z \geq 1.645$	reject H_0 if $Z \leq -1.96$ or $Z \geq 1.96$
Calculated Z-value	8.991	8.660	8.660
Reject null hypothesis?	Yes	Yes	Yes
estimated p-value	<0.0001	<0.0001	<0.0001
Median difference	(+) 3.28 °F	(+) 1.87 °F	(-) 1.15 °F
95% C.I. on median	2.77 °F to 3.58 °F	1.62 °F to 2.00 °F	1.02 °F to 1.27 °F

Table 2: Results of sign test comparisons between Tenny Creek loggers, 2003.

The sign test rejects the null hypothesis in all three comparisons with a high level of significance ($p < 0.0001$), indicating that there is strong evidence that temperatures were truly different between the three locations. The median water temperature at the pond outlet (TEN050) was 3.28 °F warmer than the inlet (TEN055). The median temperature at the mouth of Tenny Creek (TEN010) was 1.15 °F cooler than the outlet, but still 1.87 °F warmer than the pond inlet. There is a 95% chance that the true median difference between stations falls within the range of temperatures indicated by the 95% confidence intervals in Table 2.

Discussion

From July 3 to October 18 2003, heating of impounded water in the Swan Ponds did not cause downstream temperatures in Tenny Creek to exceed the state water temperature criterion (63.5 °F). There were no temperatures recorded in excess of the criterion at any of the stations.

However, the ponds did have a significant impact on stream temperature. The 7-DADMax at the outlet of the facility was 5.3 °F warmer than at the inlet, with a median difference between stations of 3.28 °F, indicating that impounded water was heated prior to discharging downstream. The maximum daily temperature fluctuation (ΔT) was also higher at the pond outlet (7.9 °F) than at the inlet (5.3 °F), suggesting greater diurnal heating of the ponded water compared to inflowing creek water.

The median temperature at the mouth of Tenny Creek was 1.15 °F lower than at the pond outlet. Stream shading and groundwater inflow probably contributed to this downstream temperature moderation. However, the median temperature at the mouth of Tenny Creek was still 1.87 °F warmer than the pond inlet, indicating that temperature increases due to the ponds had a lasting downstream effect.

Based on the relatively low temperature of Tenny Creek water above the Swan Ponds (7-DADMax = 56.9 °F), Tenny Creek is a potential source of cool water to downstream Salmon Creek during the summer months. The 7-DADMax for Salmon Creek at the Kline Pond footbridge (just downstream from the Tenny Creek confluence) was 72.1 °F in 2003. Daily maximum temperatures at this location exceeded 64 °F on 89 days.

An influx of cool water from Tenny Creek serves the dual purposes of helping to moderate stream temperatures in Salmon Creek and providing cold water refugia for temperature-stressed

organisms in this area. It is desirable to keep Tenny Creek as cold as possible in order to maximize these downstream benefits.

The primary limitation to this study is the July 3 to October 18 period of logger deployment. Peak differences between stations occurred shortly after logger deployment in July, suggesting that observed median differences between stations may have been larger had the deployment period started earlier in the summer.

Biological conditions within the Swan Ponds probably played a role in the observed water temperatures as well. During the study period, the surface of the lower pond was almost completely covered by a floating mat of duckweed (*lemna minor*). The duckweed mat appears to form each year (see 2004 photo), providing significant shading and likely reducing heating of the water column through absorption and reflectance of incident sunlight. Accidental or intentional removal of the duckweed mat through management actions (dredging, flow alteration, etc) could result in greater heating of the pond water and increased downstream temperature impacts.

Summary

- Ponding of water in the Swan Ponds facility did not cause downstream exceedences of temperature criteria in 2003.
- Water temperature at the Swan Ponds outlet was higher than at the inlet by a median of 3.28 °F.
- Water temperatures decreased somewhat between the Swan Ponds outlet and the mouth of Tenny Creek. However, temperatures at the mouth of Tenny Creek remained significantly higher than those recorded above the Swan Ponds facility.
- The presence of duckweed in the lower Swan Pond facility likely has a mitigating influence on temperature increases within the facility.
- Maintenance of cool water temperatures in Tenny Creek is desirable due to its potential mitigating effect on high summertime water temperatures in Salmon Creek.

Conclusions and Management Recommendations

Since downstream temperatures did not exceed state criteria during the study period, there is no evidence to suggest that mitigation of Swan Pond temperature impacts is required.

However, temperature impacts clearly occurred and had a measurable effect on downstream water temperatures at the mouth of Tenny Creek. The benefits of cold-water inflow to Salmon Creek were somewhat limited by the temperature increases within the Swan Ponds facility. In light of this, modifications to the Swan Ponds facility to minimize temperature impacts would be beneficial. The following actions are recommended:

- To the extent practical under current program priorities and budget limitations, the Clark County Clean Water Program should consider options to mitigate temperature impacts from the Swan Ponds facility. Possible options may include modifying the outlet structure so that water is not discharged from the surface, and decreasing residence time in the ponds.
- Management activities in the Swan Ponds facility should take precautions not to disrupt the summertime growth of duckweed.
- The results of this project also suggest that potential temperature impacts should be considered and accounted for in the future design of in-line or regional stormwater facilities.

References

Clark County Public Works, Water Resources Section. (June 2002). *Standard Procedures for Monitoring Activities*, Clark County Water Resources Section.

Helsel, D.R. and Hirsch, R.M. (1993). *Statistical Methods In Water Resources*. Elsevier Science B. V. Amsterdam, The Netherlands.